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INCIDENCE OF THERMALLY MARKED PINK, CHUM, and SOCKEYE  
SALMON IN THE COASTAL WATERS OF THE GULF OF ALASKA,  
1998

by

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## ABSTRACT

North Pacific Ocean and eastern Bering Sea research cruises conducted by the Auke Bay Laboratory Ocean Carrying Capacity (OCC) program during April and May (spring) and July and August (summer) 1998 provided ocean recoveries of 111 pink (*Oncorhynchus gorbuscha*), 342 chum (*O. keta*), and 48 sockeye (*O. nerka*) salmon thermally marked during incubation at Alaskan (USA) and Canadian hatcheries. Of these, the 86 otolith thermal marks for juvenile pink salmon, 269 otolith thermal marks for juvenile chum salmon, and 48 otolith thermal marks for juvenile sockeye salmon represent 6.5%, 20.0%, and 4.1% of our samples, respectively. The 53 otolith thermal marks for immature and maturing chum salmon and 25 otolith thermal marks for maturing pink salmon caught during May 1998 represent 11.4% and 26.3% of these samples, respectively. The 42 otolith thermal marks for immature and maturing chum salmon caught during July and August 1998 represent 4.8% of those samples.

The marked immature (age .1+) chum salmon from southeastern Alaska and Prince William Sound hatcheries and maturing pink salmon from Prince William Sound hatcheries caught during spring 1998 were found in offshore waters of the North Pacific Ocean. The marked maturing chum salmon from southeastern Alaska and Canadian hatcheries caught during spring 1998 were mostly found in nearshore waters of the North Pacific Ocean. The marked juvenile (age .0) salmon caught during summer 1998 migrated westerly along the coastal waters of the North Pacific Ocean. The marked immature (age .1+) chum salmon from southeastern Alaska and Canadian hatcheries caught during summer 1998 were found in the coastal waters of the North Pacific Ocean from Prince William Sound to the eastern Aleutian Islands and also in the coastal waters of the eastern Bering Sea.

## INTRODUCTION

Thermal marking of salmonid otoliths has become an important, cost-effective tool to identify hatchery salmon at sea. In recent years, releases of thermally marked salmon into the North Pacific Ocean from hatcheries in Washington, British Columbia, and Alaska have numbered in the billions; Alaska hatcheries alone released over 780 million thermally marked salmon into the North Pacific Ocean in 1998 (Coded Wire Tag and Otolith Processing Lab Database, Alaska Department of Fish and Game, Juneau). The large numbers of thermally marked salmon released into the North Pacific Ocean have greatly increased the probability of recovering marked salmon during high-seas sampling and have provided a unique opportunity to study the life history traits of hatchery salmonids (Ignell et al. 1997; Farley and Munk 1997; Farley and Munk 1998).

In 1996, the OCC program at the Auke Bay Laboratory, National Marine Fisheries Service initiated a comprehensive program to study the distribution, migration, origin, size, growth, and diet of juvenile, immature, and maturing salmonids in the Gulf of Alaska (Carlson et al. 1996). One objective of this ongoing program is to collect and analyze otoliths from salmonids to determine hatchery origin of these fish and to partition

hatchery from wild stocks in our samples. In this document we summarize information on recovery location and average lengths and weights at recovery for thermally marked pink (*Oncorhynchus gorbuscha*), chum (*O. keta*), and sockeye (*O. nerka*) salmon caught in the Gulf of Alaska during April and May (spring) and July and August (summer) 1998.

## **CRUISE**

During 1998, the OCC program conducted two surveys to describe the distribution of juvenile, immature, and maturing salmon in the North Pacific Ocean. The first survey began in April (hereafter referred to as the spring cruise) and sampled salmon in coastal waters and offshore waters of the North Pacific Ocean (Carlson et al. 1998; Figure 1). The second survey began in July (hereafter referred to as the summer cruise) and sampled coastal waters of the North Pacific Ocean from Dixon Entrance to Cape Prominence off of Unimak Island (Carlson et al. 1998; Figure 2).

The fishing gear was a midwater rope trawl, model 400/580, made by Cantrawl Pacific Ltd.<sup>1</sup> of Richmond, B.C. The net is 198 m long, has hexagonal mesh in the wings and body, and has a 1.2-cm mesh liner in the codend. The net was fished with three 60 m, 1.9-cm bridles attached at a single point to steel alloy 5-m midwater trawl doors, each weighing 463 kg. Floats were attached to the headrope to help keep the headrope near the surface. The net was towed for 1 hour at 5 knots with approximately 260 m of warp line on each door. The net was monitored using a Simrad 300 netsounder, which showed a typical spread of 52 m horizontally and 18 m vertically.

Catches were brought aboard, and the codend was emptied onto a sorting table. Juvenile (first ocean year; ocean age .0), immature (second or third ocean year; ocean age .1 or older), and maturing salmon and other fishes were identified and sorted by species, and length and weight were recorded for subsamples of each fish species. Juvenile salmon and heads taken from immature and maturing salmon were frozen for further laboratory analyses. A scale was taken from the preferred area (when possible) to determine age and brood year.

## **LABORATORY ANALYSES**

In the laboratory, juvenile salmon and heads of immature and maturing salmon were thawed and fork length and weight were recorded for subsamples of juvenile pink, chum, and sockeye salmon. Left and right sagittal otoliths were removed, and the left sagittal otoliths mounted, using thermal resin, on petrographic slides and then ground to expose the primordia. If left sagittal otoliths were not available or were overground, then the right sagittal otoliths were used. Otolith microstructure was examined under a compound microscope, and the microstructure patterns were compared to thermal mark patterns from voucher specimens collected from the hatcheries before release. All otoliths were read independently by a second reader to assure accuracy and confidence in the readings

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<sup>1</sup> Reference to trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

(Hagen et al. 1995). When disagreements between otolith readers occurred, they were resolved by the most experienced otolith reader.

Scales and otoliths from immature and maturing salmon were jointly examined to determine age and brood year. If discrepancies in age or brood year occurred between the otolith and scale readings, then we referred to the age and brood year from the salmon scale.

## **PRELIMINARY FINDINGS**

### **Thermal Marks**

#### *Spring Cruise*

A total of 107 maturing pink, and 506 immature and maturing chum were caught in the Gulf of Alaska during spring 1998. A subsample of 95 maturing pink salmon and 465 immature and maturing chum salmon were analyzed for hatchery marks. Otolith thermal mark patterns were found from seven discrete hatchery release site locations including Prince William Sound hatcheries (Armin F. Koernig, Cannery Creek, Solomon Gulch, and Wally Noerenberg hatcheries), southeastern Alaska hatcheries (Gastineau and Hidden Falls), and a Canadian hatchery (Nitinat) (Figure 3). The 53 otolith thermal marks for immature and maturing chum salmon and 25 otolith thermal marks for maturing pink salmon recovered during spring 1998 represent 11.4% and 26.3% of these samples, respectively.

#### *Summer Cruise*

A total of 18,594 juvenile and 541 maturing pink, 3,487 juvenile and 1,233 immature and maturing chum, and 2,296 juvenile sockeye salmon were caught in the coastal waters of the Gulf of Alaska during summer 1998. A subsample of 1,322 juvenile pink salmon, 1,352 juvenile and 880 immature and maturing chum salmon, and 1,211 juvenile sockeye salmon were analyzed for hatchery marks. Otolith thermal mark patterns were found from fourteen discrete hatchery release site locations (Figure 3). The 86 otolith thermal marks for juvenile pink salmon, 269 otolith thermal marks for juvenile chum salmon, and 48 otolith thermal marks for juvenile sockeye salmon represent 6.5%, 20.0%, and 4.1% of our samples, respectively. The 42 otolith thermal marks for immature and maturing chum salmon caught during summer 1998 represent 4.8% of those samples.

### **Fish Distribution**

#### *Spring Cruise*

Most of the pink salmon from Prince William Sound hatcheries released during spring of 1997 were distributed between 42° N and 46° N along 145° W longitude (Figure 4). Immature chum salmon released in the spring of 1997 were distributed between 42° N and

46° N along 145° W longitude; whereas maturing chum salmon released in the springs of 1994 and 1995 were distributed northwest along the continental shelf from Cape St. Elias to Cape Chiniak (Figure 5). All of the thermally marked salmon were recovered between 4 May and 19 May 1998.

### *Summer Cruise*

All of the juvenile hatchery origin salmon caught during the survey had been released in the spring of 1998 and recovered between 24 July and 4 August 1998 (Figures 6 - 8). Pink salmon from Prince William Sound hatcheries were distributed southwest along the continental shelf from Cape Puget to Cape Chiniak. Chum salmon from Canadian hatcheries (Nitinat) were distributed northwest along the continental shelf from Cape Spencer to Cape Douglas. Most of the chum salmon from southeastern Alaska hatcheries were distributed northwest along the continental shelf from Cape Spencer to Cape Douglas; however, one chum salmon from Gastineau Hatchery was found southeast of Cape Spencer in the nearshore area at Cape Ommaney. Chum salmon from Prince William Sound hatcheries were distributed southwest along the continental shelf from Cape Puget to Cape Chiniak. Sockeye salmon from release sites in southeastern Alaska and Canada were distributed northwest along the continental shelf from Cape Spencer to Cape Chiniak.

Four distinct brood years (1993 - 1996) of immature and maturing hatchery origin chum salmon (released in the springs of (1994 –1997)) were recovered between 27 July and 11 August 1998 (Figure 9). Chum salmon from Gastineau and Hidden Falls hatcheries in southeastern Alaska and Nitinat Hatchery on the southwestern corner of Vancouver Island, British Columbia were found along the continental shelf and oceanic waters from Cape Spencer to Cape Prominence and also in the southeastern Bering Sea. Chum salmon from Prince William Sound hatcheries were distributed along the continental shelf from Cape Puget to Cape Prominence.

### **Size**

Sizes of juvenile pink, chum, and sockeye salmon recoveries varied widely among hatcheries, and in some instances, large standard deviations for lengths and weights were found for a given hatchery, even among fish captured in the same area (Table 1). In general, mean lengths and weights of hatchery juvenile pink and chum salmon increased with distance offshore and as fish migrated westward. Sizes of immature and maturing chum and maturing pink salmon by hatchery, brood year, and date recovered are given in Tables 2 and 3. In general, length and weight of immature and maturing chum and maturing pink salmon contained large standard deviations. This is indicative of the variation in growth of chum salmon where standard deviation of length and weight increases as ocean age increases.

## DISCUSSION

This was the third year of ocean sampling of salmon in the Gulf of Alaska and southeastern Bering Sea by the OCC program. Results of the 1996 and 1997 surveys (Farley and Munk 1997; Farley and Munk 1998) indicated a large proportion of thermally marked pink (29.7%; 22.8%) and chum (20.6%; 31.2%) salmon in the juvenile salmon samples. Results during 1998, however, suggest a lower proportion of thermally marked pink salmon (6.5%) and chum salmon (20.0%) in our juvenile salmon samples. This decline has several possible explanations: 1) changes in our sampling strategy between years, 2) sub-sampling methods, 3) changes in migration patterns, or 4) dramatic increase in the numbers of wild pink salmon from southeastern Alaska and Prince William Sound.

Whereas the proportion of thermally marked juvenile pink and chum salmon declined in our 1998 samples, the proportion of thermally marked immature/maturing chum salmon increased; the thermal mark rate for immature/maturing chum salmon was 3.7% for the 1997 summer survey and 4.8% during the 1998 summer survey. This increase could have been due to the inclusion of hatcheries releasing thermally marked chum salmon from Prince William Sound during 1997 (brood year 1996) that were not actively marking chum salmon for release during 1996 (brood year 1995).

The ocean distribution of thermally marked salmon differed by age, species, and region of origin. Thermally marked juvenile salmon captured during the summer cruise were found on the continental shelf from nearshore waters to as far as the 200 m shelf break and were distributed from southeastern Alaska to as far west as Kodiak Island. Thermally marked immature salmon captured during the summer cruise were found along the continental shelf and also in oceanic waters beyond the 200 m shelf break; most of the immature salmon were distributed between Gore Point which is west of Prince William Sound and Cape Prominence on Unalaska Island. This was the first year of sampling in the Gulf of Alaska during spring, and our results indicate that thermally marked pink salmon from Prince William Sound hatcheries were generally distributed in offshore (oceanic) waters. Thermally marked immature chum salmon from Prince William Sound and southeastern Alaska hatcheries were also located in oceanic waters, whereas most of the thermally marked maturing chum salmon were found in coastal waters of the Gulf of Alaska.

Past studies of southeastern and central Alaska pink and chum salmon stocks have provided the following conceptual models on their distribution and migration (Hartt and Dell 1986; Figures 10 and 11). Juvenile pink and chum salmon begin to enter the coastal waters of the Gulf of Alaska by late June. The majority of juvenile salmon migrate westward along the continental shelf of the Gulf of Alaska and begin moving off the continental shelf to oceanic waters west of Kodiak Island during late summer and fall. During fall and winter, pink and chum salmon migrate southward and eastward, extending well offshore in oceanic waters of the Gulf of Alaska and over a broad geographical range from east to west and north to south. During spring and early summer, maturing pink and immature chum salmon migrate northward and westward to

the coastal waters of the Gulf of Alaska, whereas maturing chum salmon primarily migrate northward towards the coastal waters of the Gulf of Alaska. After reaching the coastal waters of the Gulf of Alaska, maturing chum salmon stocks bound for southeastern Alaska, British Columbia, Washington, and Oregon migrate eastward, then southward along the coast to their home streams (Neave et al. 1976).

Our results suggest a similar migration and distribution pattern for hatchery origin pink and chum salmon from Prince William Sound, southeastern Alaska, and British Columbia. During the spring cruise, the largest catches of immature hatchery origin chum salmon occurred in oceanic waters of the Gulf of Alaska from 42 N to 46 N along the 145 W line whereas the largest catches of maturing hatchery origin chum salmon occurred along the continental shelf from Cape Chiniak to Cape St. Elias. During the summer cruise, the largest catches of juvenile hatchery origin pink and chum salmon were found in the coastal waters of the Gulf of Alaska. All juvenile hatchery origin pink and chum salmon were generally caught west of their initial release locations suggesting a westerly migration movement around the Gulf of Alaska. The largest catches of immature hatchery origin chum salmon were found in the coastal waters of the Gulf of Alaska from Cape Puget to Cape Prominence suggesting a possible northward and westward migration of these stocks during late spring and early summer. The largest catches of maturing southeastern Alaska and Canadian hatchery origin chum salmon occurred between Cape Spencer and Ocean Cape suggesting an eastward, then southward migration along the coast to their natal hatcheries.

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Table 1. Mean lengths and weights and standard deviations (in parenthesis) of 86 hatchery pink, 269 hatchery chum, and 48 hatchery sockeye salmon juveniles recovered in the Gulf of Alaska during July and August 1998. (See Figure 3 for hatchery and release site locations)

Species	Date recovered	Lat. north	Long. west	Armin F. Koernig				Cannery Creek				Wally Noerenberg				Solomon Gulch																			
				Mean		SD		Mean		SD		Mean		SD		Mean		SD																	
				length	weight			length	weight			length	weight			length	weight																		
				n	(mm)	SD	(g)	n	(mm)	SD	(g)	n	(mm)	SD	(g)	n	(mm)	SD	(g)	n	(mm)	SD	(g)												
Pink	8/1/1998	59° 52'	148° 27'	2	118	(1.4)	15	(0.9)	4	114	(5.8)	13	(1.7)	6	117	(8.6)	14	(4.3)	6	122	(8.4)	15	(4.3)												
	8/1/1998	59° 23'	148° 26'						2	118	(6.4)	14	(3.7)					1	128	(0.0)	16	(0.0)													
	8/2/1998	59° 07'	150° 52'						2	146	(32.5)	31	(20.9)					1	143	(0.0)	28	(0.0)													
	8/2/1998	58° 48'	150° 16'						2	126	(1.4)	18	(0.4)	3	143	(9.0)	28	(4.8)	10	133	(11.3)	23	(5.8)												
	8/3/1998	58° 51'	153° 08'						1	168	(0.0)	52	(0.0)																						
	8/3/1998	58° 50'	152° 17'	1	126	(0.0)	16	(0.0)					1	147	(0.0)	29	(0.0)	7	147	(9.2)	29	(6.7)													
	8/3/1998	58° 47'	151° 30'	1	126	(0.0)	19	(0.0)	2	105	(11.3)	11	(2.3)					2	150	(2.1)	30	(2.8)													
	8/4/1998	57° 07'	150° 52'	14	133	(9.6)	24	(5.4)	2	127	(11.3)	20	(6.9)	1	144	(0.0)	30	(0.0)	15	144	(9.3)	30	(6.6)												
Chum				Nitinat				Gastineau				Hidden Falls				Armin F. Koernig				Port Chalmers				Wally Noerenberg											
				Mean		SD		Mean		SD		Mean		SD		Mean		SD		Mean		SD		Mean		SD									
				length	weight			length	weight			length	weight			length	weight			length	weight			length	weight										
				n	(mm)	SD	(g)	n	(mm)	SD	(g)	n	(mm)	SD	(g)	n	(mm)	SD	(g)	n	(mm)	SD	(g)	n	(mm)	SD	(g)	n	(mm)	SD	(g)				
		7/24/1998	54° 57'	133° 16'	1	160	(0.0)	45	(0.0)																										
		7/25/1998	56° 06'	135° 00'	2	169	(5.7)	45	(6.6)																										
		7/25/1998	55° 53'	135° 32'					1	136	(0.0)	25	(0.0)																						
		7/27/1998	58° 11'	136° 52'					9	133	(11.8)	21	(7.0)	5	136	(8.6)	24	(5.5)																	
		7/27/1998	58° 02'	137° 22'	2	161	(2.8)	41	(3.7)																										
		7/27/1998	57° 54'	137° 42'	2	163	(0.0)	43	(3.9)					2	141	(4.9)	23	(1.1)																	
		7/28/1998	59° 26'	139° 56'					1	156	(0.0)	38	(0.0)																						
		7/28/1998	59° 15'	140° 14'	1	163	(0.0)	46	(0.0)	13	135	(11.0)	24	(6.4)	10	137	(9.8)	25	(5.3)																
		7/28/1998	58° 58'	140° 37'	1	175	(0.0)	54	(0.0)	6	146	(7.0)	31	(6.9)	4	139	(5.1)	25	(2.8)																
		7/30/1998	59° 37'	144° 48'					1	136	(0.0)	25	(0.0)	11	134	(9.1)	23	(5.0)																	
		7/30/1998	59° 30'	144° 46'					1	137	(0.0)	20	(0.0)	3	132	(5.0)	23	(2.3)																	
		8/1/1998	59° 52'	148° 27'					5	129	(5.6)	19	(3.6)	4	139	(5.9)	26	(3.7)			3	142	(1.5)	26	(1.7)	18	129	(8.5)	20	(3.7)					
		8/1/1998	59° 23'	148° 26'					9	141	(12.2)	27	(6.5)	4	147	(7.0)	29	(3.5)								2	139	(5.7)	23	(5.3)					
		8/1/1998	59° 03'	148° 25'					2	143	(2.1)	30	(1.8)	1	143	(0.0)	27	(0.0)																	
		8/2/1998	59° 07'	150° 52'	5	168	(25.3)	54	(24.5)	17	144	(8.2)	29	(5.3)	6	142	(5.3)	29	(3.0)							1	132	(0.0)	22	(0.0)					
		8/2/1998	58° 48'	150° 16'	2	186	(0.7)	68	(0.6)	9	144	(7.1)	30	(4.6)	4	134	(1.7)	23	(1.0)			1	156	(0.0)	40	(0.0)	2	128	(5.7)	20	(1.9)				
		8/3/1998	58° 50'	152° 41'	2	186	(0.0)	74	(8.8)																5	137	(6.4)	24	(3.0)						
		8/3/1998	58° 50'	152° 17'	5	178	(24.8)	63	(23.8)	12	156	(9.5)	38	(8.9)							2	127	(14.1)	23	(2.6)	1	154	(0.0)	36	(0.0)	20	143	(19.0)	31	(17.4)
		8/3/1998	58° 47'	151° 30'	1	180	(0.0)	61	(0.0)	20	146	(9.9)	33	(8.6)	14	140	(5.9)	28	(3.4)	1	146	(0.0)	33	(0.0)			2	135	(14.9)	26	(9.6)				
		8/4/1998	57° 07'	150° 52'												1	150	(0.0)	35	(0.0)						2	148	(5.0)	30	(4.5)					
Chum				Boat Harbor				Limestone Inlet																											
				Mean		SD		Mean		SD				SD				SD				SD				SD									
				length	weight			length	weight			length	weight			length	weight			length	weight														
				n	(mm)	SD	(g)	n	(mm)	SD	(g)	n	(mm)	SD	(g)	n	(mm)	SD	(g)	n	(mm)	SD	(g)	n	(mm)	SD	(g)	n	(mm)	SD	(g)				
		7/27/1998	58° 11'	136° 52'	2	141	(9.9)	25	(5.9)	1	144	(0.0)	29	(0.0)																					
		7/28/1998	59° 15'	140° 14'					1	136	(0.0)	23	(0.0)																						
		7/28/1998	58° 58'	140° 37'	1	131	(0.0)	20	(0.0)																										
	7/30/1998	59° 37'	144° 48'					2	145	(6.4)	27	(1.1)																							
	8/3/1998	58° 50'	152° 17'	1	163	(0.0)	43	(0.0)	1	147	(0.0)	38	(0.0)																						
	8/3/1998	58° 47'	151° 30'	1	136	(0.0)	27	(0.0)																											

Table 1 (con't). Mean lengths and weights and standard deviations (in parenthesis) of 86 hatchery pink, 269 hatchery chum, and 48 hatchery sockeye salmon juveniles recovered in the Gulf of Alaska during July and August 1998. (See Figure 3 for hatchery and release site locations)

Species	Date recovered	Lat. north	Long. west	Sweetheart				Chilkat				Tuya				Speel Arm				Tahltan				Tatsamenie								
				Mean				Mean				Mean				Mean				Mean				Mean								
				length	weight	n	SD	length	weight	n	SD	length	weight	n	SD	length	weight	n	SD	length	weight	n	SD	length	weight	n	SD					
				(mm)	(g)			(mm)	(g)			(mm)	(g)			(mm)	(g)			(mm)	(g)			(mm)	(g)			(mm)	(g)			
Sockeye	7/27/1998	58° 02'	137° 22'																													
	7/28/1998	59° 15'	140° 14'					1	123	(0.0)	21	(0.0)	2	142	(17.7)	30	(11.1)	15	131	(8.0)	23	(4.3)	2	153	(0.7)	36	(0.8)	2	129	(9.9)	23	(2.6)
	7/28/1998	58° 58'	140° 37'										1	132	(0.0)	23	(0.0)	1	154	(0.0)	36	(0.0)	1	153	(0.0)	36	(0.0)					
	8/1/1998	59° 52'	148° 27'															2	112	(35.4)	15	(11.5)										
	8/1/1998	59° 23'	148° 26'															2	160	(6.4)	37	(5.9)					1	136	(0.0)	25	(0.0)	
	8/1/1998	59° 03'	148° 25'															1	168	(0.0)	57	(0.0)										
	8/2/1998	59° 07'	150° 52'															1	142	(0.0)	29	(0.0)					2	155	(7.8)	37	(5.2)	
	8/2/1998	58° 48'	150° 16'																							1	142	(0.0)	32	(0.0)		
	8/3/1998	58° 51'	153° 08'										1	200	(0.0)	83	(0.0)	3	197	(14.7)	81	(16.9)										
	8/3/1998	58° 50'	152° 41'															1	187	(0.0)	72	(0.0)										
	8/3/1998	58° 47'	151° 30'	1	153	(0.0)	37	(0.0)					1	156	(0.0)	43	(0.0)	4	163	(4.5)	44	(1.7)										
	8/4/1998	57° 30'	151° 50'															1	122	(0.0)	24	(0.0)										

Table 2. Mean lengths and weights and standard deviations (in parenthesis) of 95 immature and maturing hatchery chum salmon recovered in the Gulf of Alaska during May 1998 and July and August 1998. Underline numbers (n) indicate maturing chum salmon; all others are immature chum salmon. (See Figure 3 for hatchery and release site locations)

Species	Date recovered	Lat. north	Long. west	Nitinat					Gastineau					Hidden Falls					Armin F. Koernig					Wally Noerenberg				
				length		Mean weight		BY	length		Mean weight		BY	length		Mean weight		BY	length		Mean weight		BY	length		Mean weight		BY
				n	(mm)	SD	(g)		n	(mm)	SD	(g)		n	(mm)	SD	(g)		n	(mm)	SD	(g)		n	(mm)	SD	(g)	
Chum	5/4/1998	50° 01'	160° 07'	<u>1</u>	554	(0.0)	1900	(0.0)	94																			
	5/7/1998	52° 45'	152° 23'											<u>1</u>	582	(0.0)	2200	(0.0)	94									
	5/10/1998	57° 35'	152° 04'	<u>1</u>	706	(0.0)	4400	(0.0)	94																			
	5/13/1998	59° 45'	144° 49'							<u>1</u>	744	(0.0)	5400	(0.0)	93	<u>1</u>	714	(0.0)	5000	(0.0)	93							
	5/13/1998	59° 37'	144° 46'							<u>5</u>	693	(22.6)	4040	(304.9)	93													
										<u>2</u>	622	(17.7)	3200	(282.8)	94													
	5/13/1998	59° 29'	144° 46'							<u>1</u>	690	(0.0)	4200	(0.0)	93	<u>2</u>	603	(8.5)	2600	(141.4)	94							
	5/13/1998	59° 13'	144° 48'	<u>1</u>	604	(0.0)	-	-	93	<u>1</u>	583	(0.0)	-	-	93													
	5/18/1998	45° 57'	145° 00'																			2	308	(53.0)	400	(141.4)	96	
	5/19/1998	44° 58'	145° 00'							<u>3</u>	403	(76.6)	-	-	95	3	415	(30.4)	-	-	95	1	365	(0.0)	-	-	96	
										3	330	(21.8)	-	-	96	5	349	(30.6)	-	-	96							
	5/19/1998	43° 57'	145° 00'							2	329	(19.1)	-	-	96	3	348	(23.1)	-	-	96							
	5/19/1998	42° 57'	145° 00'													3	331	(18.9)	402	(55.9)	96							
	7/27/1998	57° 46'	138° 04'							1	380	(0.0)	600	(0.0)	96													
	7/27/1998	58° 11'	136° 52'							<u>1</u>	674	(0.0)	3800	(0.0)	93	4	607	(17.4)	2575	(221.7)	94							
										<u>4</u>	607	(16.5)	2825	(320.2)	94													
	7/28/1998	59° 26'	139° 56'	<u>1</u>	663	(0.0)	4100	(0.0)	94	<u>1</u>	743	(0.0)	5200	(0.0)	94	1	605	(0.0)	2800	(0.0)	94							
				<u>1</u>	680	(0.0)	4600	(0.0)	95																			
	8/1/1998	59° 52'	148° 27'																			1	389	(0.0)	690	(0.0)	96	
	8/1/1998	59° 23'	148° 26'																									
	8/1/1998	59° 03'	148° 25'	1	397	(0.0)	790	(0.0)	96	1	367	(0.0)	640	(0.0)	96	1	373	(0.0)	690	(0.0)	96							
	8/2/1998	59° 07'	150° 52'							3	404	(3.8)	833	(55.1)	96													
	8/2/1998	58° 48'	150° 16'													1	367	(0.0)	640	(0.0)	96							
8/3/1998	58° 47'	151° 30'																										
8/4/1998	57° 12'	151° 02'																										
8/4/1998	57° 07'	150° 52'							2	407	(31.1)	845	(275.8)	96	1	491	(0.0)	1220	(0.0)	95								
8/7/1998	55° 03'	156° 53'	1	445	(0.0)	1000	(0.0)	96							1	540	(0.0)	1900	(0.0)	95								
8/9/1998	53° 44'	164° 09'													1	460	(0.0)	1190	(0.0)	95								
8/10/1998	53° 37'	164° 05'																										
8/10/1998	53° 28'	164° 00'																										
8/11/1998	53° 22'	166° 42'													1	507	(0.0)	1400	(0.0)	95								
															1	359	(0.0)	570	(0.0)	96	1	380	(0.0)	670	(0.0)	96		
8/11/1998	53° 16'	166° 37'	1	515	(0.0)	1510	(0.0)	95							1	454	(0.0)	990	(0.0)	96	1	363	(0.0)	520	(0.0)	96		

Table 2 (con't). Mean lengths and weights and standard deviations (in parenthesis) of 95 immature and maturing hatchery chum salmon recovered in the Gulf of Alaska during May 1998 and July and August 1998. Underline numbers (n) indicate maturing chum salmon; all others are immature chum salmon. (See Figure 3 for hatchery and release site locations)

Species	Date recovered	Lat. north	Long. west	Port Chalmers				
				length		Mean weight		
				<i>n</i>	(mm)	SD	(g)	SD BY
Chum	5/19/1998	44° 58'	145° 00'	2	336	(19.8)	-	- 96
	5/19/1998	43° 57'	145° 00'	2	303	(17.1)	-	- 96
	8/1/1998	59° 52'	148° 27'	1	385	(0.0)	680 (0.0)	96

Table 3. Mean lengths and weights and standard deviations (in parenthesis) of 25 maturing (brood year 1996) hatchery pink salmon recovered in the Gulf of Alaska during May 1998. (See Figure 3 for hatchery and release site locations)

Species	Date recovered	Lat. north	Long. west	Armin F. Koernig				Cannery Creek				Solomon Gulch				Wally Noerenberg					
				Mean				Mean				Mean				Mean					
				length		weight		length		weight		length		weight		length		weight			
				<i>n</i>	(mm)	SD	(g)	SD	<i>n</i>	(mm)	SD	(g)	SD	<i>n</i>	(mm)	SD	(g)	SD	<i>n</i>	(mm)	SD
Pink	5/7/1998	51° 47'	151° 30'									1	432	(0.0)	900	(0.0)					
	5/15/1998	55° 03'	145° 01'									1	444	(0.0)	865	(0.0)					
	5/16/1998	52° 59'	144° 59'									4	441	(13.4)	875	(110.9)					
	5/18/1998	46° 58'	145° 00'	2	409	(3.5)	665	(7.1)									1	376	(0.0)	680	(0.0)
	5/18/1998	45° 57'	145° 00'	2	398	(0.7)	650	(70.7)	1	376	(0.0)	600	(0.0)				2	396	(26.9)	700	(141.4)
	5/19/1998	44° 58'	145° 00'	2	379	(58.0)	-	-	5	389	(20.8)	600	(81.7)				2	421	(33.2)	700	(141.4)
	5/19/1998	43° 57'	145° 00'	1	395	(0.0)	600	(0.0)													
	5/19/1998	42° 57'	145° 00'	1	370	(0.0)	501	(0.0)													

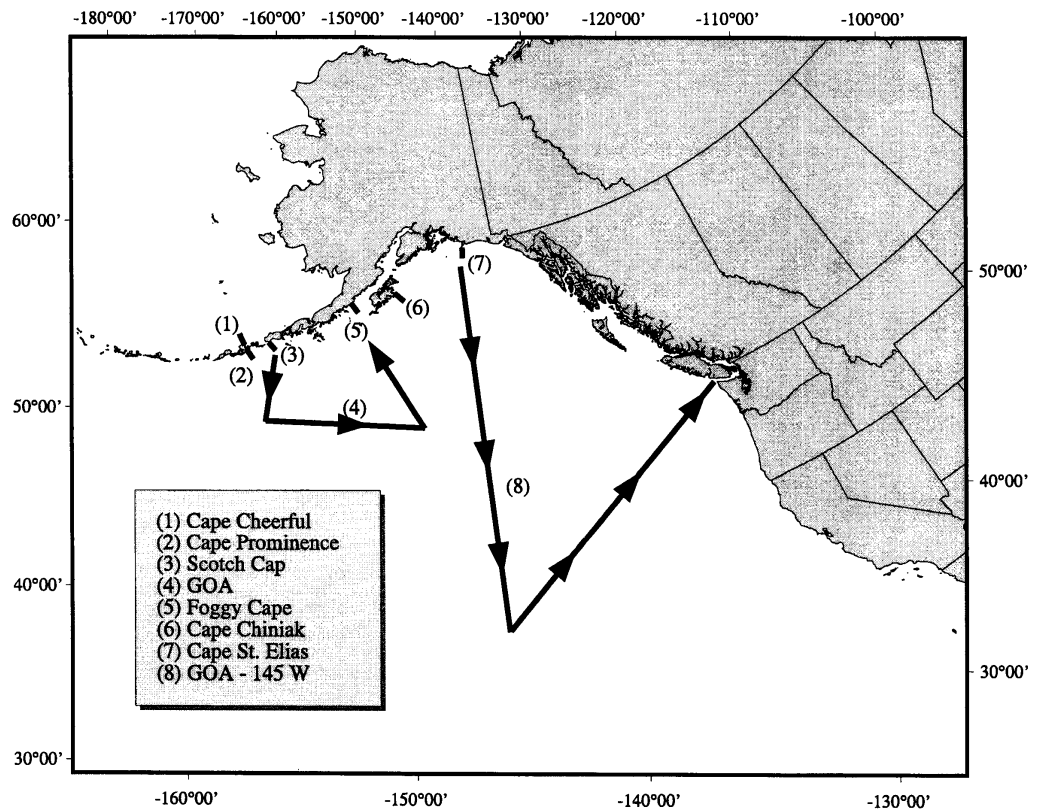


Figure 1. Overview map of the North Pacific Ocean showing area covered and transects sampled by the F/V GREAT PACIFIC during May 1998.

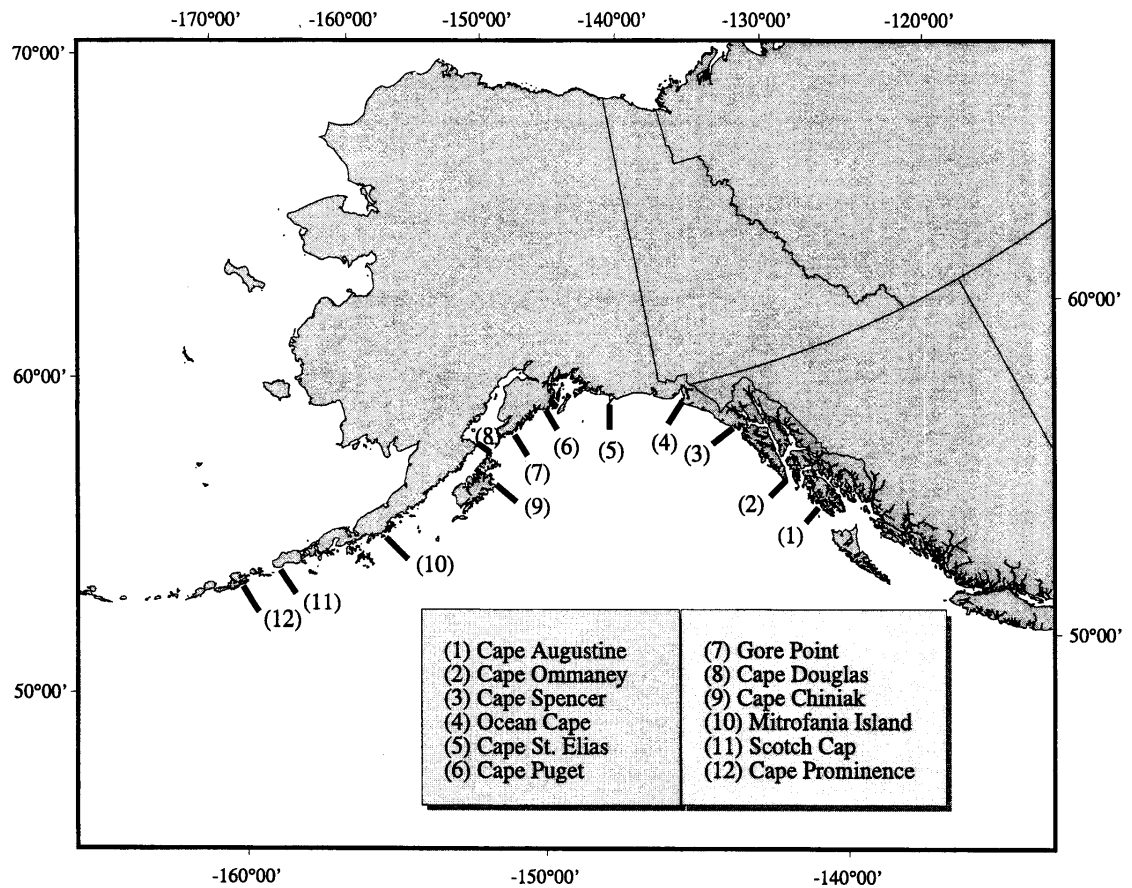


Figure 2. Overview map of the North Pacific Ocean showing area covered and transects sampled by the F/V GREAT PACIFIC during July - August 1998.

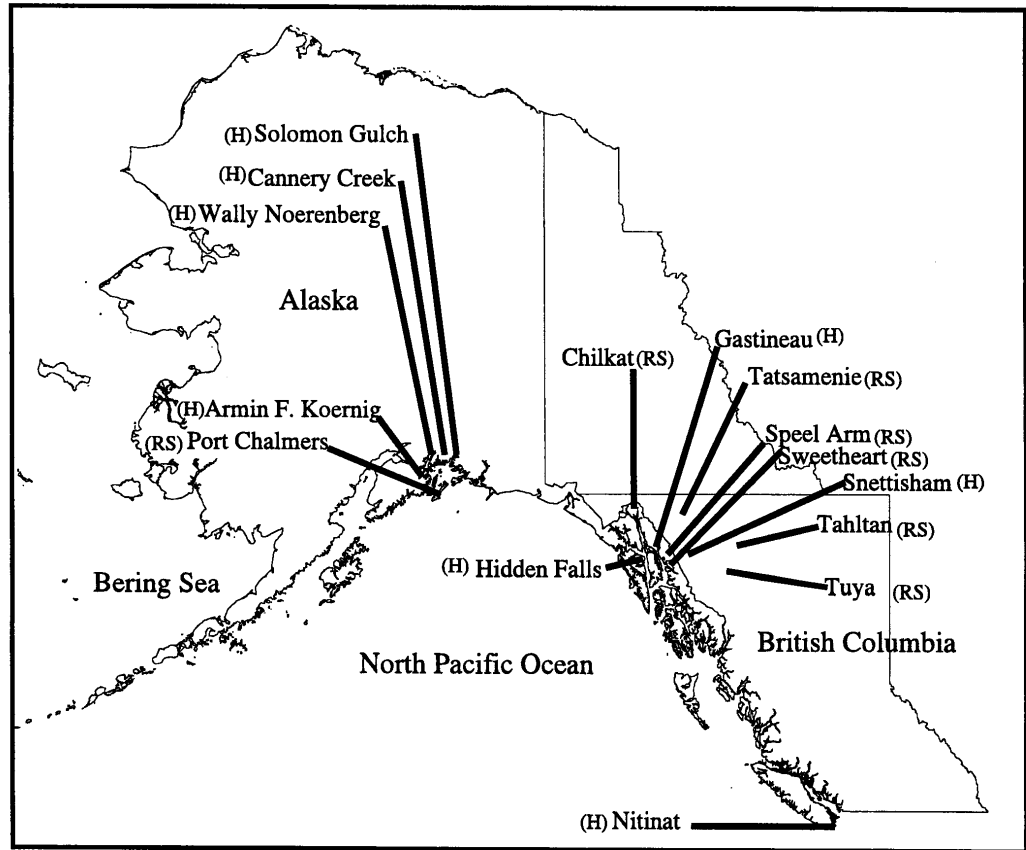


Figure 3. Locations of hatcheries (H) and release sites (RS) for thermally marked salmon.



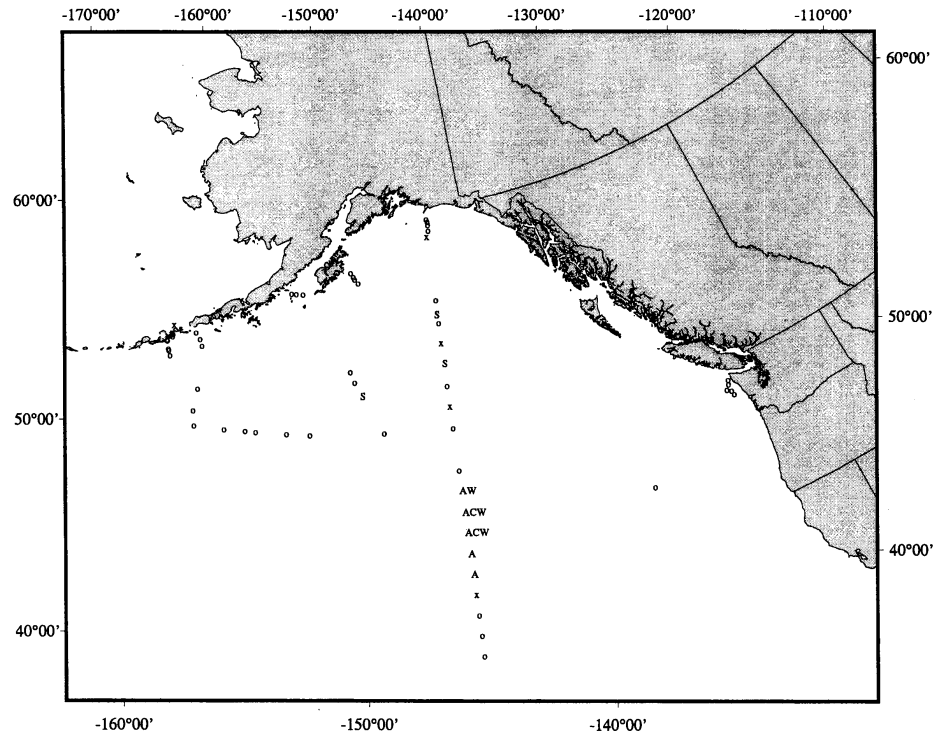


Figure 4. Distribution of maturing hatchery pink salmon recovered during May 1998, where x indicates trawl location where pink salmon were caught, but no thermally marked pink salmon were caught; o indicates trawl location where no pink salmon were caught; letters indicate location where hatchery pink salmon were caught. Hatcheries represented include: Armin F. Koernig (A), Cannery Creek (C), Solomon Gulch (S), and Wally Noerenberg (W).

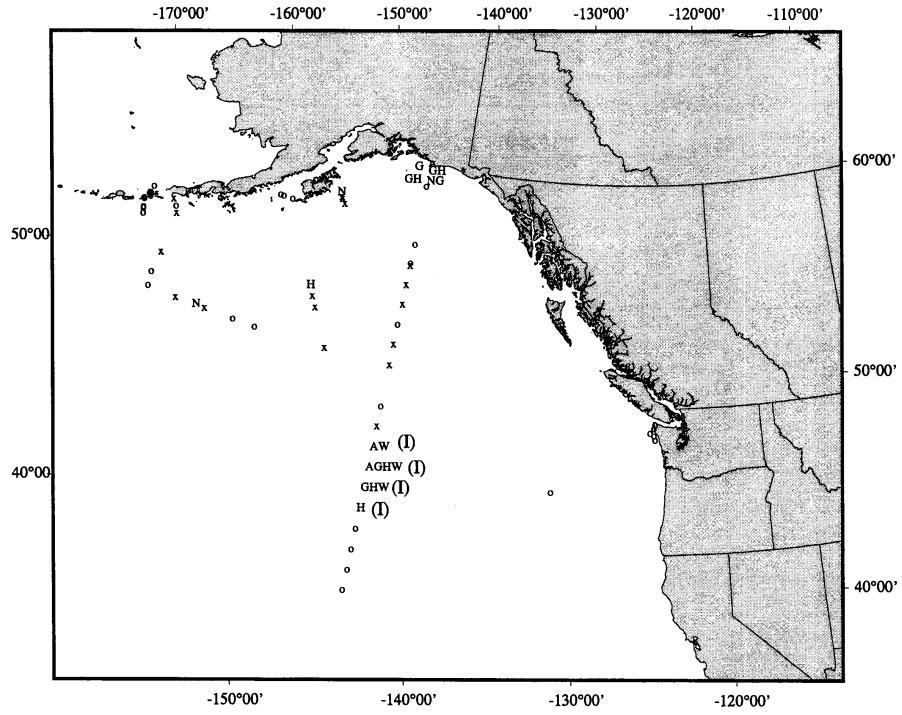


Figure 5. Distribution of immature (I) and maturing (all others) chum salmon recovered during May 1998, where x indicates trawl location where chum salmon were caught, but not thermally marked chum salmon were caught; o indicates trawl location where no chum salmon were caught; letters indicate location where hatchery chum salmon were caught. Hatcheries represented include: Armin F. Koernig (A), Gastineau (G), Hidden Falls (H), Nitinat (N), and Wally Noerenberg (W).

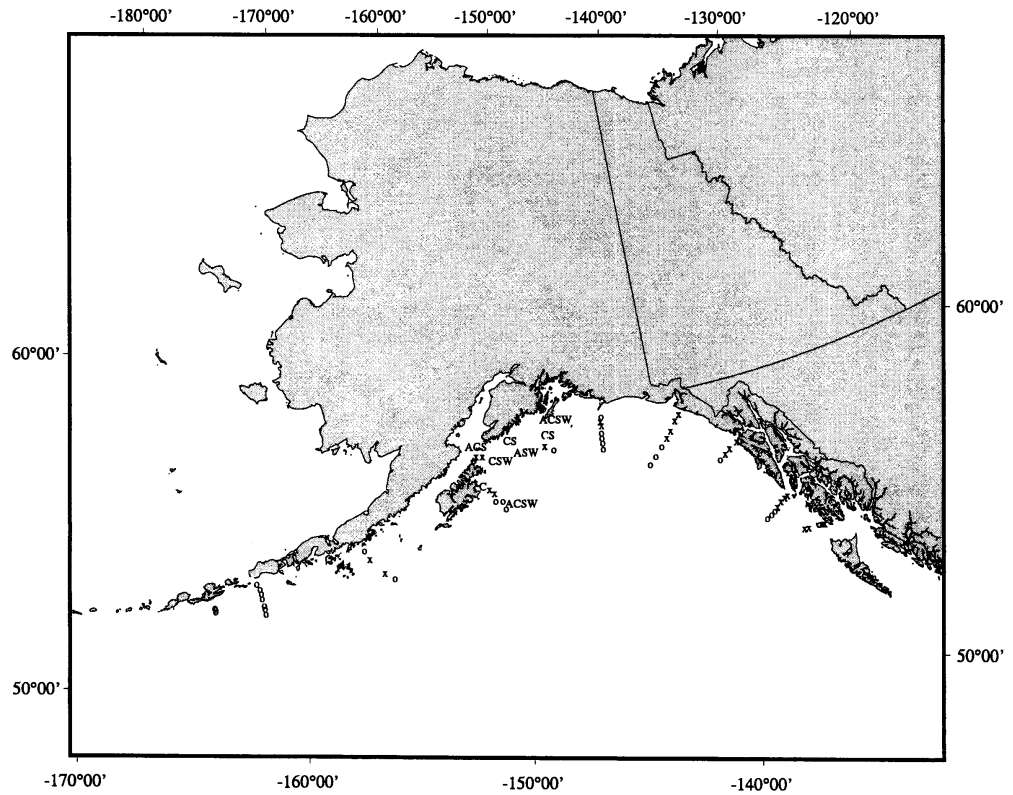


Figure 6. Distribution of juvenile pink salmon recovered during July/August 1998, where x indicates trawl location where pink salmon were caught, but no thermally marked pink salmon were caught; o indicates trawl location where no pink salmon were caught; letters indicate location where hatchery pink salmon were caught. Hatcheries represented include: Armin F. Koernig (A), Cannery Creek (C), Solomon Gulch (S), and Wally Noerenberg (W).

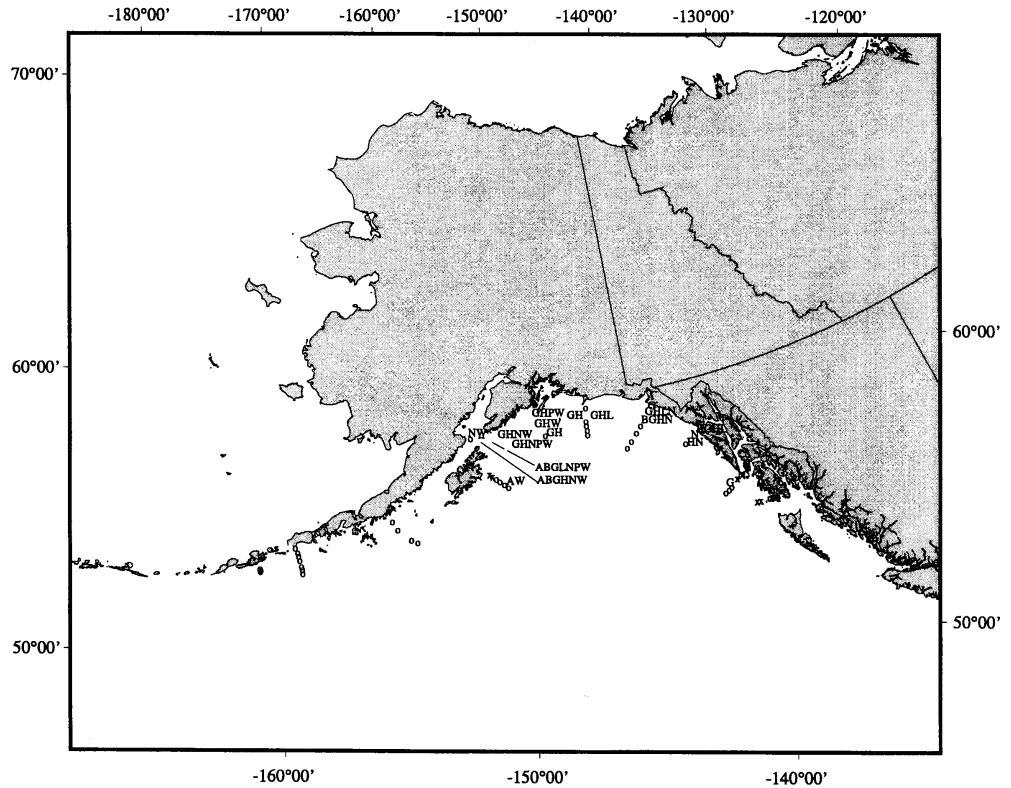


Figure 7. Distribution of juvenile chum salmon recovered during July/August 1998, where x indicates trawl location where pink salmon were caught, but no thermally marked chum salmon were caught; o indicates trawl location where no chum salmon were caught; letters indicate location where hatchery chum salmon were caught. Hatcheries represented include: Armin F. Koernig (A), Boat Harbor (B), Gastineau (G), Hidden Falls (H), Limestone Inlet (L), Nitinat (N), Port Chalmers (P), and Wally Noerenberg (W).

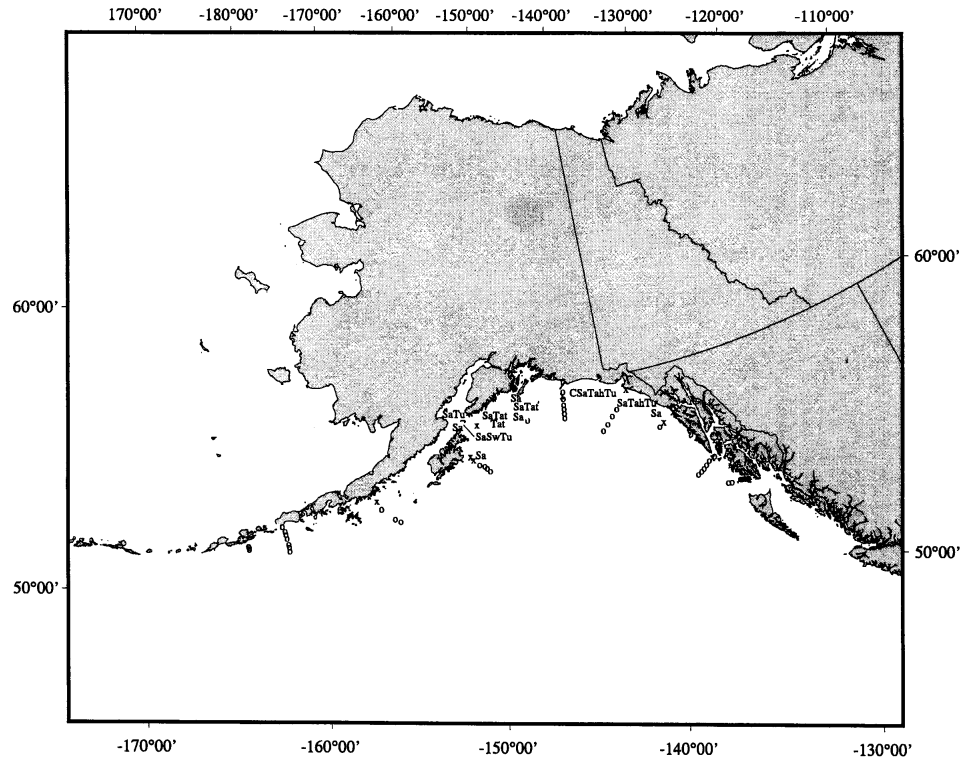


Figure 8. Distribution of juvenile sockeye salmon recovered during July/August 1998, where x indicates trawl location where sockeye salmon were caught, but no thermally marked chum salmon were caught; o indicates trawl location where no sockeye salmon were caught; letters indicate location where hatchery sockeye salmon were caught. Release sites include: Chilkat (C), Speel Arm (Sa), Sweetheart (Sw), Tahlitan (Ta), Tatsamenie (Tat), and Tuya (Tu).

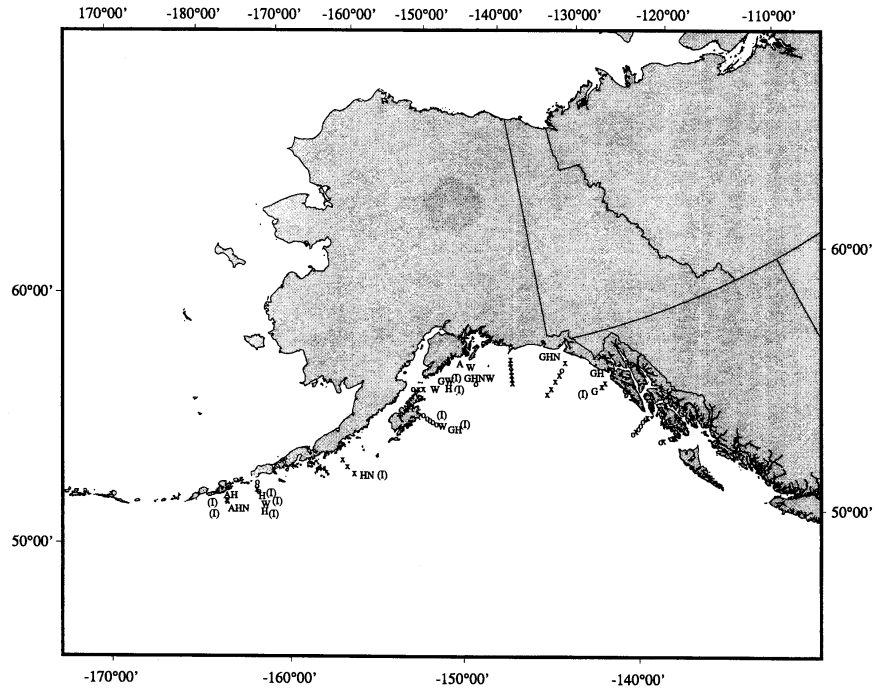


Figure 9. Distribution of immature (I) and maturing (all others) chum salmon recovered during July/August 1998, where x indicates trawl location where chum salmon were caught, but no thermally marked chum salmon were caught; o indicates trawl location where no chum salmon were caught; letters indicate location where hatchery chum salmon were caught. Hatcheries represented include: Armin F. Koernig (A), Gastineau (G), Hidden Falls (H), Nitinat (N), and Wally Noerenberg (W).

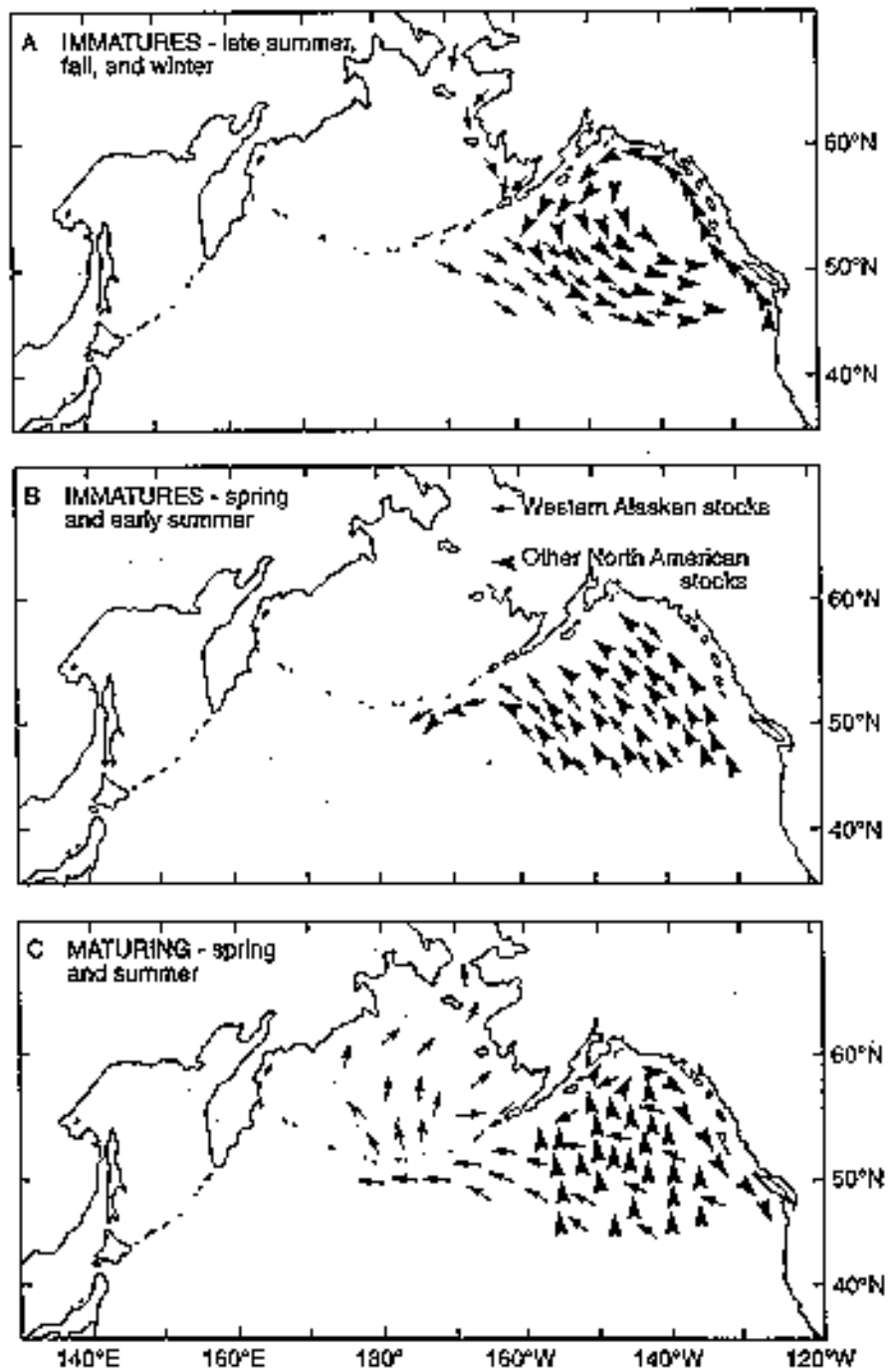


Figure 10. Model of migration of North American chum salmon. (From Fredin et al. 1977)

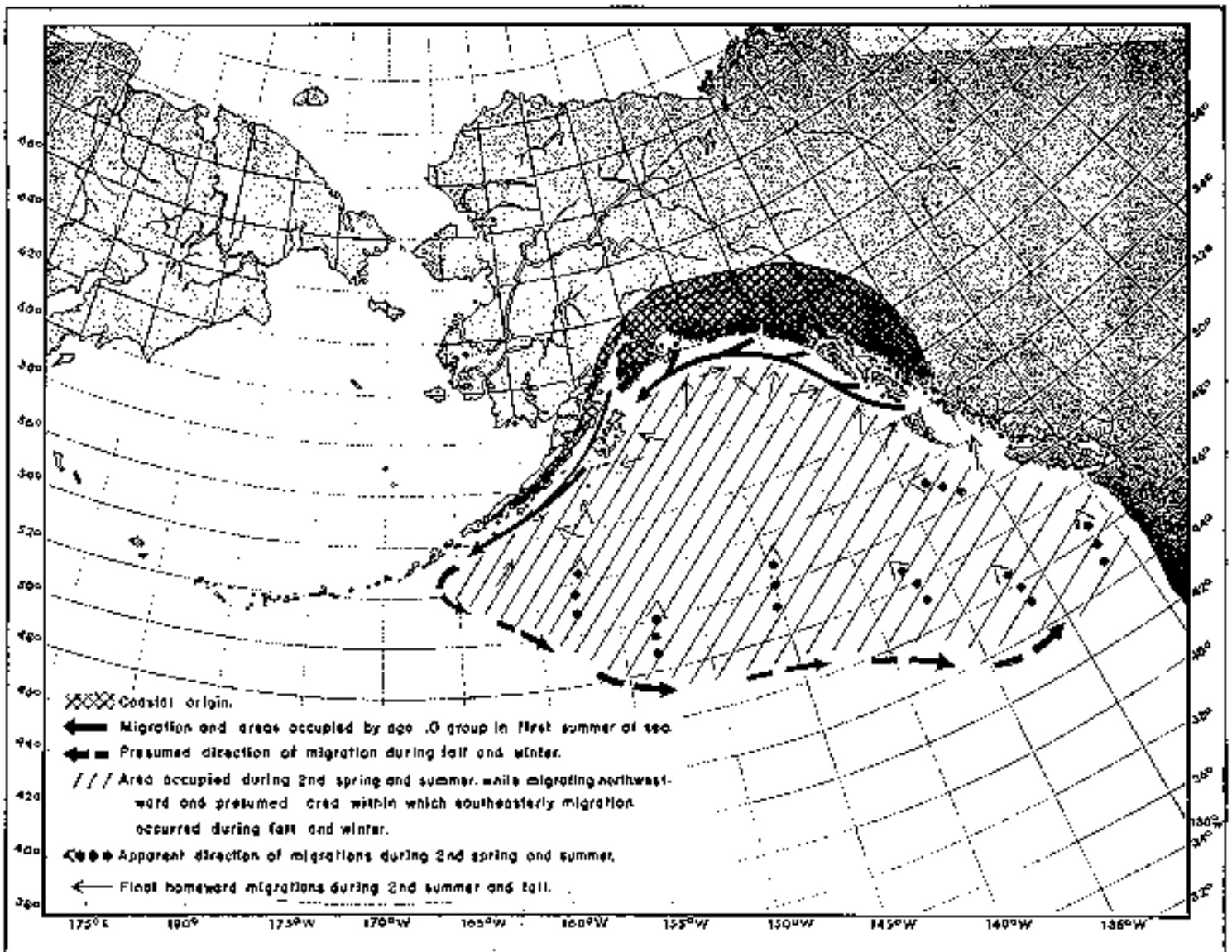


Figure 11. Model of migration of North American pink salmon. (From Takagi et al. 1981)